

WHO SHOULD SIT AT THE EXIT ROW? A HUMAN FACTORS APPROACH TO EMERGENCY EVACUATION PASSENGER SELECTION IN COMMERCIAL AVIATION

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Abstract

Emergency exit row seating allocation represents a critical yet underexamined safety decision in commercial aviation. While regulations establish minimum criteria for passengers occupying these positions, significant gaps exist between regulatory intent and operational practice. This research develops a comprehensive framework for assessing optimal passenger characteristics for emergency exit responsibilities through an evolutionary methodological approach integrating Hierarchical Task Analysis (HTA), Event Analysis of Systemic Teamwork (EAST), and Work Domain Analysis (WDA) based on Cognitive Work Analysis principles. Data collection comprised semi-structured interviews with four Brazilian aviation professionals using the Critical Decision Method (CDM) protocol, complemented by documentary analysis of regulatory documents from Brazil (RBAC 121), the United States (FAA 14 CFR § 121.585), and Japan (JCAB regulations), as well as accident investigation reports. HTA decomposed emergency exit operation into 17 discrete task elements, while EAST captured distributed cognition demands across four critical incident narratives. WDA identified six systemic constraints explaining implementation failures, including age contradictions in regulations, commercial prioritization over safety criteria, and the absence of positive selection frameworks. International comparative analysis revealed significant regulatory divergences, with Japan employing objective BMI criteria and explicitly defined vulnerable categories, while Brazil presents vague criteria lacking operational definition. Analysis of the JAL516 successful evacuation (January 2024) demonstrated that crew training and organizational culture were the primary success factors rather than systematic passenger selection. The research proposes evidence-based recommendations including age criteria harmonization, positive selection implementation systems, multi-stage verification protocols, and structural decoupling of emergency seat allocation from commercial revenue systems.

Keywords: Aviation Safety, Emergency Evacuation, Passenger Selection, Human Factors, Cognitive Work Analysis

1 Introduction

Emergency evacuation in commercial aviation constitutes a complex sociotechnical system where the interaction between technology, procedures, and human behaviour directly determines safety outcomes [1, 2]. The collision at Tokyo Haneda Airport on 2 January 2024, in which all 379 occupants of Japan Airlines Flight 516 (an Airbus A350-941) were successfully evacuated before the aircraft was destroyed by fire, demonstrated both the potential and the critical vulnerabilities of current evacuation systems [3]. The success of this evacuation has been widely attributed to rigorous crew training and a strong organizational safety culture rather than to the systematic selection of passengers occupying emergency exit row seats.

Regulatory frameworks governing emergency exit row seating vary considerably across jurisdictions. In the United States, 14 CFR § 121.585 mandates individual briefing of exit row passengers and enumerates specific eligibility criteria, including physical capability, language comprehension, and willingness to assist [4]. Japanese regulations, administered by the Japan Civil Aviation Bureau (JCAB), employ objective anthropometric criteria such as Body Mass Index (BMI) ranges of 18.5 to 30 and define explicit age boundaries (15–60 years), along with enumerated vulnerable categories [5]. Brazilian regulations (RBAC 121) require that passengers demonstrate the

“capacity to perform functions” associated with emergency exit operation, yet this language lacks operational specificity and leaves considerable room for subjective interpretation by crew members [6].

Despite the safety-critical nature of exit row seating decisions, there is a notable paucity of systematic research examining the passenger selection process from a human factors perspective. Existing literature has addressed evacuation dynamics [7], crew resource management [8], and cabin safety design [9], but has not comprehensively analysed the decision-making framework underlying passenger selection for emergency exit positions. This gap is particularly consequential given the dual-use nature of these seats: airlines routinely monetize exit row positions as premium products, creating an inherent tension between commercial objectives and safety optimization.

This research addresses this gap through an evolutionary methodological approach integrating three complementary human factors methods: Hierarchical Task Analysis (HTA) [10], Event Analysis of Systemic Teamwork (EAST) [2], and Work Domain Analysis (WDA) based on Cognitive Work Analysis (CWA) principles [1]. The integration of these methods enables a multi-layered analysis that captures both the functional task requirements of emergency exit operation and the systemic constraints that prevent optimal passenger selection practices.

2 Methodology and Technical Foundation

The research employs a three-phase evolutionary methodology, with each phase building upon the findings of the preceding one. This progressive analytical structure allows for iterative refinement of the research framework and ensures methodological complementarity across analytical perspectives. Figure 1 illustrates the three phases, their respective methods, and the outputs generated at each stage.

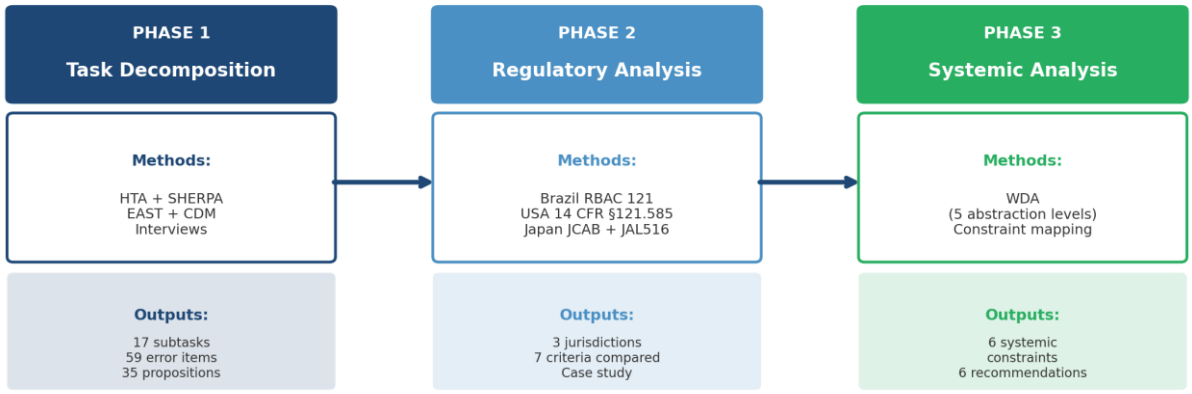


Figure 1 – Three-phase evolutionary methodology overview.

2.1 Phase 1: Task Decomposition (HTA and EAST)

Phase 1 utilized Hierarchical Task Analysis (HTA), following Annett and Duncan [10], to decompose emergency exit operation into discrete task elements. The analysis identified 17 subtasks organized across four primary phases: pre-evacuation assessment, evacuation initiation, passenger flow management, and post-evacuation procedures. A Systematic Human Error Reduction and Prediction Approach (SHERPA) matrix was applied to each subtask, classifying potential errors according to a taxonomy that includes detection failures (D), information processing errors (IP), action errors (A), timing errors (T), communication errors (C), decision errors (DE), and information retrieval failures (IR). The SHERPA analysis encompassed 59 error lines spanning all HTA subtasks. Figure 2 presents the resulting task decomposition across the four evacuation phases.

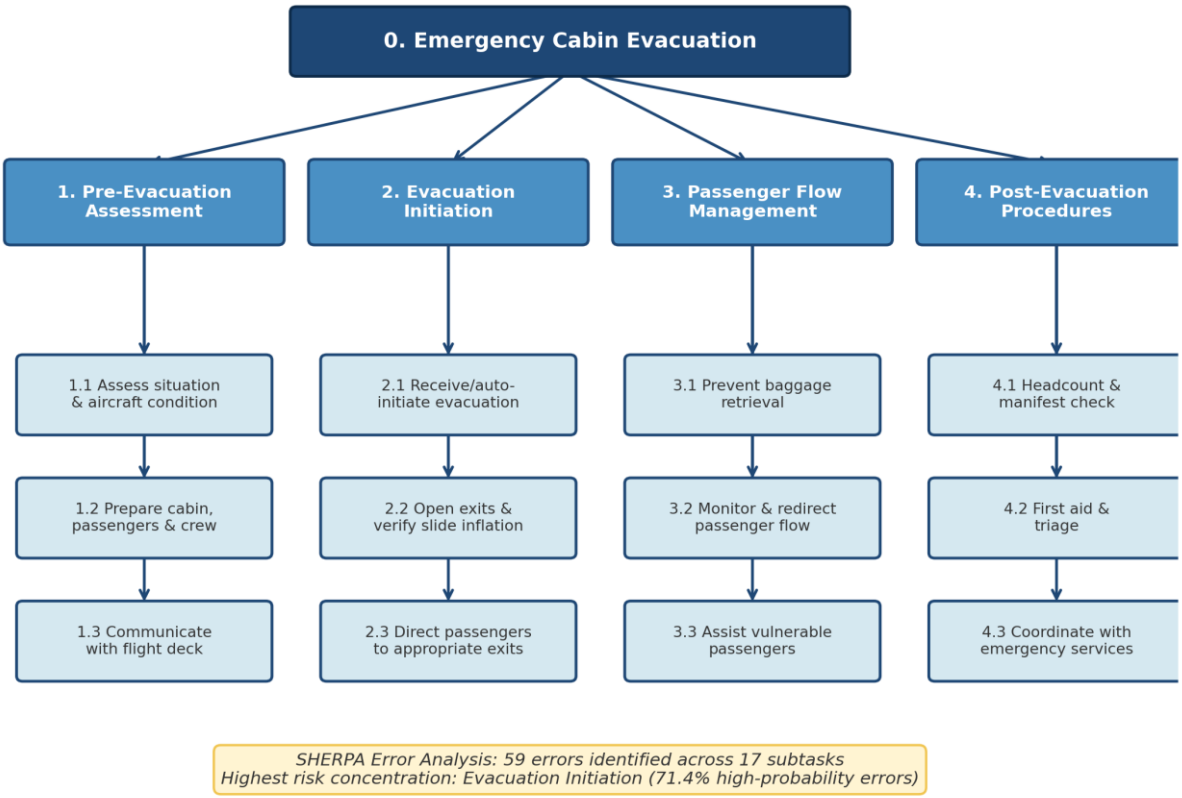


Figure 2 – Hierarchical Task Analysis decomposition of emergency cabin evacuation.

Concurrently, Event Analysis of Systemic Teamwork (EAST) [2] was applied to capture distributed cognition demands during emergency scenarios. Four semi-structured interviews were conducted with Brazilian aviation professionals using the Critical Decision Method (CDM) protocol [11]. Participants included two flight attendants (one with 30 years of experience including 20 years as an aircraft manufacturer instructor, and one with 34 years of experience as cabin chief and neuropsychologist specializing in crew mental health) and two military pilots (one lieutenant colonel helicopter pilot with 27 years of experience, and one captain aviator with 3 years of experience). All participants provided informed consent for recording and transcription. Interview identities were anonymized as Interviewees 001 through 004.

The CDM protocol elicited detailed narratives of critical incidents involving emergency situations and passenger behaviour. Four distinct incident types emerged: engine failure during helicopter flight, in-flight smoke emergency requiring electrical shutdown, runway excursion with full passenger load (109 passengers), and emergency landing preparation for landing gear malfunction. EAST propositional network analysis yielded 35 propositions across the four incidents, classified by relation type (perception, cognition/assumption, communication, and coordination).

2.2 Phase 2: Regulatory Comparative Analysis

Phase 2 conducted a systematic comparative analysis of emergency exit row regulations across three jurisdictions: Brazil (ANAC RBAC 121), the United States (FAA 14 CFR § 121.585), and Japan (JCAB/MLIT regulations as implemented by Japan Airlines and All Nippon Airways). Documentary analysis included regulatory texts, airline operational procedures, and the Japan Transport Safety Board (JTSB) interim report on the JAL516 collision at Haneda Airport [3]. This phase also examined the European regulatory framework (EASA Regulation EU No 965/2012) as a supplementary reference point.

2.3 Phase 3: Systemic Constraints Analysis (WDA)

Phase 3 applied Work Domain Analysis (WDA) following Rasmussen's taxonomy [1, 12] to map systemic constraints across five abstraction levels: functional purposes, values and priority measures, purpose-related functions, object-related processes, and physical objects. The WDA framework, as demonstrated by Schmid, Korn and Stanton [13] in their analysis of reduced-crew operations in

commercial aviation, provides a structured approach for identifying the purposive and physical constraints that shape workers' behaviour within complex sociotechnical systems. This phase synthesized findings from Phases 1 and 2 to identify systemic barriers to optimal passenger selection implementation.

3 Results

3.1 HTA and SHERPA Findings

The HTA decomposition revealed that emergency exit operation requires the coordinated execution of tasks spanning physical manipulation (operating door/window mechanisms weighing 11–16 kg), cognitive processing (assessing external conditions before opening exits), communication (comprehending and following crew commands), and decision-making under time pressure (the 90-second evacuation certification requirement).

The SHERPA analysis revealed that error probability concentrates in the initial phases of evacuation. The evacuation initiation phase exhibited the highest proportion of high-probability errors (10 of 14 items, or 71.4%), followed by the pre-evacuation phase (11 of 17, or 64.7%). Passenger management showed moderate error concentration (6 of 16, or 37.5%), while post-evacuation errors were comparatively lower (2 of 12, or 16.7%). Detection errors (D) exhibited the highest risk rating, with 100% classified as high probability. The most recurrent consequences identified were injuries (38 occurrences), delays (20 occurrences), congestion (5 occurrences), and unsafe exit opening (5 occurrences). Figure 3 summarizes these distributions by evacuation phase and by error taxonomy.

Six primary selection criteria emerged from the integrated HTA and EAST analysis: (1) Physical capability, defined as muscular strength of at least 200 N, rapid mobility, and overhead reach capacity; (2) Cognitive capacity, encompassing decision-making under pressure and appropriate stress response; (3) Communication ability, including language proficiency and assertiveness; (4) Absence of impairments affecting visual, auditory, or mobility capabilities; (5) Willingness to assist crew members during evacuation; and (6) Social responsibility factors, specifically the absence of dependent care responsibilities that could divide attention during an emergency.

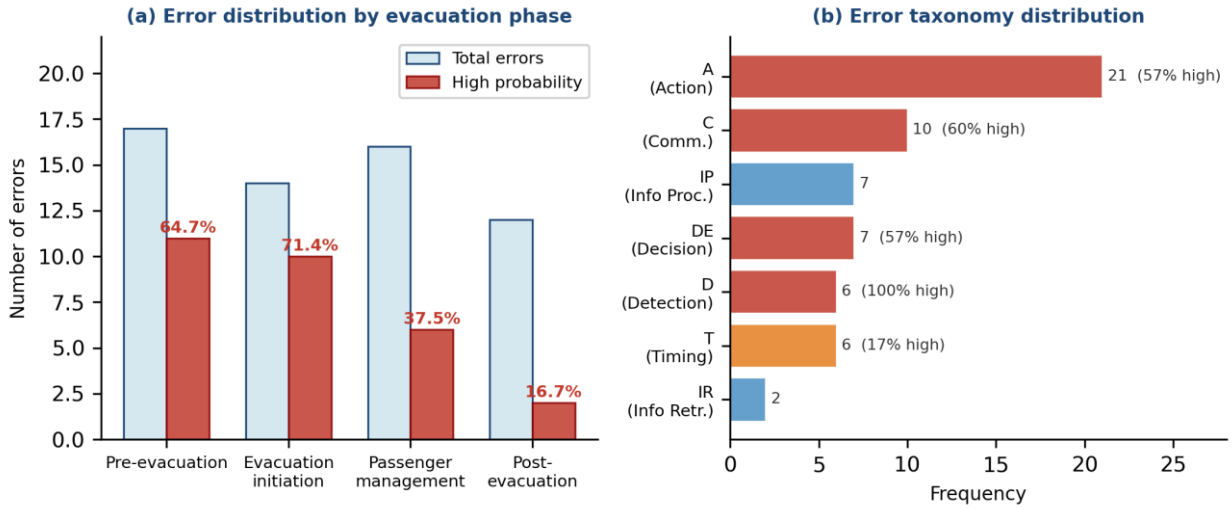


Figure 3 – SHERPA error distribution: (a) by evacuation phase; (b) by error taxonomy.

3.2 EAST Propositional Network Analysis

The EAST analysis of four critical incident narratives revealed consistent patterns in information flow, decision-making, and crew–passenger interaction during emergencies. Three key findings emerged with direct implications for passenger selection criteria. Figure 4 depicts the propositional network synthesized from the four incident narratives, mapping the information flow among crew members, passengers, technical systems, and knowledge sources during emergency evacuation.

First, hierarchical communication structures serve as stabilizing mechanisms during emergencies. In both helicopter incidents reported by the military pilots, the exercise of command authority was the primary factor in controlling crew panic. As Interviewee 002 reported regarding an inexperienced mechanic during a smoke emergency: the crew member exhibited extreme distress, but the pilot's hierarchical authority and calm instruction contained the situation. This finding suggests that passengers with prior experience in hierarchical command structures (such as military or emergency

services personnel) may perform more effectively in exit row positions.

Second, crew members engage in continuous informal assessment of passenger capabilities during boarding. Interviewee 001, with 30 years of cabin crew experience, described a naturalistic screening process based on body language observation, eye contact patterns, and verbal cues that flight attendants develop through accumulated operational experience. This screening identifies passengers who demonstrate fear (protective posturing, clutching personal items), those under medication influence, and those who may lack physical capability. However, this assessment remains entirely informal and lacks standardization across airlines or regulatory frameworks.

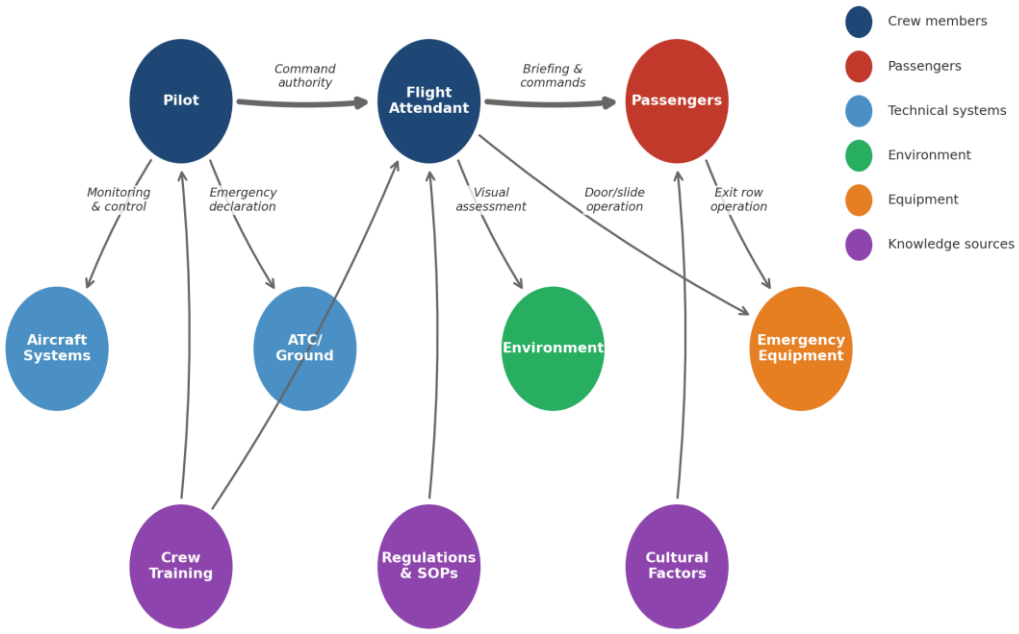


Figure 4 – EAST propositional network: information flow during emergency evacuation.

Third, the unpredictability of human behaviour under extreme stress emerged as a universal theme across all interviews. Interviewee 001 noted that it is very difficult to define passenger typologies suitable for emergency exit seating due to the fundamental unpredictability of human behaviour, noting that individuals who appear physically and psychologically capable may exhibit completely different responses during actual emergencies. Interviewee 002, drawing on 27 years of military aviation, emphasized that even highly trained personnel can freeze in life-threatening situations, making it practically impossible to predict individual behaviour with certainty.

3.3 International Regulatory Comparison

The comparative regulatory analysis revealed significant divergences in approach and specificity across the three primary jurisdictions examined. Table 1 presents the key eligibility criteria side by side, highlighting the contrasts in regulatory precision.

Criterion	Brazil (RBAC 121)	USA (14 CFR §121.585)	Japan (JCAB)
Minimum age	16 years	15 years	15 years (airlines may set 16)
Maximum age	Not explicit (60+ excluded in practice)	None specified	60–75 (airline-specific)
Physical criteria	“Capacity to perform functions” (vague)	Physical capability to operate exit	BMI 18.5–30; explicit force req.
Language	Portuguese or English	English (or airline-required)	Japanese or English
Individual briefing	Required	Required (detailed)	Required

Crew authority	Final discretion	Can reallocate at any time	Verification at check-in/boarding
BMI / anthropo-metric	Not addressed	Not addressed	Explicitly defined

Table 1 – Comparative analysis of emergency exit row regulations across three jurisdictions.

As shown in Table 1, Japan's regulatory approach is notably more prescriptive, incorporating objective anthropometric measures and explicitly defining vulnerable categories (pregnant women, nursing mothers, unaccompanied minors, persons with reduced mobility, and passengers responsible for children or animals). The United States mandates detailed individual briefing with enumerated eligibility criteria but relies on qualitative assessment. Brazil's regulatory language is the most general, leaving operational definition to airline interpretation and crew judgment.

3.4 JAL516 Case Analysis

Analysis of the JAL516 evacuation at Haneda Airport on 2 January 2024 provided critical insights into the factors that determine evacuation success [3]. Despite the aircraft sustaining complete destruction by fire, all 367 passengers and 12 crew members were evacuated successfully. The JTSB interim report and supplementary analysis identified several factors contributing to this outcome: highly disciplined crew performance under extreme conditions, passenger compliance with crew instructions (attributed in part to Japanese cultural norms of collective discipline), effective communication protocols despite smoke-filled cabin conditions, and the presence of airline employees among the passengers who actively assisted the evacuation effort.

Critically, the evacuation succeeded despite not all exits being usable due to fire conditions on portions of the aircraft. The rear cabin sections were rapidly compromised by smoke, requiring rapid redirection of passenger flow. This case underscores that passenger selection for exit row positions has operational significance: passengers who can operate exits independently and rapidly represent a material contribution to evacuation capability. However, the case also demonstrates that crew training and organizational culture are the dominant determinants of evacuation outcomes, with passenger selection representing an optimization opportunity rather than a primary safety mechanism.

3.5 WDA: Systemic Constraints Identified

The Work Domain Analysis identified six systemic constraints that explain the persistent gap between the technical knowledge of what constitutes an effective exit row passenger and the actual implementation of selection practices. Figure 5 presents the Abstraction Hierarchy developed for this domain, mapping the five levels from functional purposes down to physical objects. The six constraints identified cut across multiple levels of this hierarchy, as detailed below.

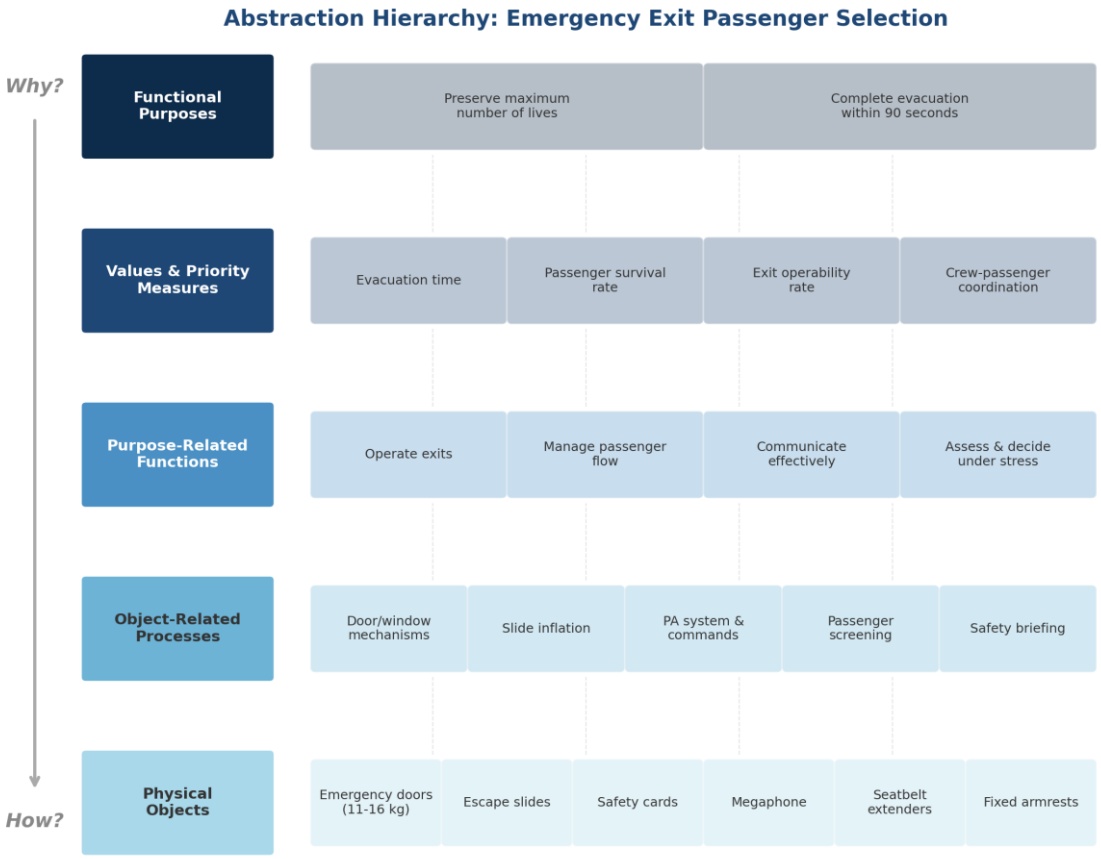


Figure 5 – Work Domain Analysis: Abstraction Hierarchy for emergency exit passenger selection.

Constraint 1: Age contradictions in regulations. Current Brazilian regulations effectively exclude passengers over 60 years of age from exit row seating. However, RBAC 67 permits pilots to maintain valid Aeronautical Medical Certificates and operate aircraft until age 65. This creates an internally contradictory regulatory framework in which a professional deemed medically qualified to command an aircraft is simultaneously considered incapable of operating its emergency exits. As Interviewee 004 reported: it is embarrassing to ask a 65-year-old captain to vacate an exit row seat when he is qualified to fly the aircraft itself.

Constraint 2: Commercial prioritization over safety. Airlines systematically monetize exit row seats as premium products with additional legroom, prioritizing revenue generation over safety-based passenger allocation. Online booking systems permit self-selection without capability verification, and the commercial incentive to fill these seats creates institutional resistance to more restrictive selection criteria. The commercial argument, as identified through interviews, centres on the statistical rarity of evacuation events as justification for maintaining revenue-oriented allocation.

Constraint 3: Absence of positive selection criteria. Across all three jurisdictions examined, regulations define who should not occupy exit row seats (exclusion criteria) without establishing who should preferentially occupy them (inclusion criteria). This reactive approach misses the opportunity to optimize safety by proactively identifying and positioning the most capable passengers. The HTA analysis demonstrates that exit row operation requires specific competencies (physical strength, cognitive processing under stress, communication ability) that could be positively assessed.

Constraint 4: Seatbelt extender complications. No jurisdiction examined explicitly prohibits the use of seatbelt extenders in exit row positions, despite the fact that passengers requiring extenders may have reduced mobility in the confined space adjacent to emergency exits. Interview data suggests that prohibiting extender use in exit rows would serve as a practical proxy measure for ensuring adequate passenger mobility without requiring explicit anthropometric assessment.

Constraint 5: Screening process deficiencies. The passenger screening process contains multiple potential failure points without adequate redundancy. Three verification stages exist (online purchase,

check-in, and boarding), but each relies on different information sources and assessment criteria, with inconsistencies between stages. Automated systems may block passengers based on declared age but cannot assess physical capability, while boarding-gate assessment depends on individual crew judgment under time pressure.

Constraint 6: Inadequate safety briefings. Current exit row briefings transfer declarative knowledge (what to do) but not procedural knowledge (how to do it under stress). Interview data confirmed that the last information received before an emergency is the most readily activated by the brain under stress, validating the neuroscientific basis for pre-departure briefings. However, without procedural rehearsal, briefing effectiveness in actual emergencies remains uncertain. Furthermore, interview evidence documented cases of premature exit opening by passengers driven by survival bias, suggesting that current briefings may inadequately address the distinction between authorized and unauthorized exit operation.

4 Discussion

The evolutionary integration of HTA, EAST, and WDA reveals a fundamental misalignment between the technical requirements of emergency exit operation and the regulatory and commercial systems governing passenger selection. The HTA analysis establishes clear, evidence-based competency requirements for exit row passengers, while the WDA demonstrates that systemic constraints systematically prevent these requirements from being implemented in practice.

A central finding is the tension between exclusion-based and inclusion-based selection approaches. All current regulatory frameworks operate on an exclusion model: they define categories of passengers who must not occupy exit rows. This approach, while administratively simpler, fails to optimize the safety contribution of exit row positioning. The interview data, particularly from the experienced cabin crew members, suggests that positive selection criteria could meaningfully improve evacuation readiness. For example, aviation professionals (off-duty pilots, cabin crew), military personnel, and emergency services workers possess training and psychological preparedness directly relevant to exit row responsibilities.

The JAL516 case analysis reinforces this perspective. The presence of airline employees among the passengers, who instinctively assisted in the evacuation process, illustrates the operational value of trained individuals in passenger positions during emergencies. This observation supports the proposal for a hierarchical positive selection system that prioritizes trained professionals for exit row positions when available.

The application of CWA methodology, as demonstrated in related aviation domains by Schmid, Korn and Stanton [13] for reduced-crew operations analysis, provides a robust framework for understanding the constraints that shape behaviour in complex sociotechnical systems. The present research extends this approach to the cabin safety domain, demonstrating that CWA methods can reveal systemic barriers that remain invisible to traditional safety analysis focused on individual task performance.

Several limitations of this research must be acknowledged. The interview sample, while providing rich qualitative data from experienced professionals, is limited to four participants within the Brazilian aviation context. The CDM protocol captures retrospective accounts of critical incidents, which are subject to recall bias and narrative construction effects. The regulatory comparison, while covering three major jurisdictions, does not encompass all relevant regulatory environments. Future research should expand the participant sample, incorporate human-in-the-loop simulation studies to validate selection criteria under controlled conditions, and conduct cross-cultural comparative analyses of passenger behaviour during evacuation scenarios.

5 Evidence-Based Recommendations

Based on the integrated findings of this research, the following recommendations are proposed for regulatory authorities and airline operational practice:

First, age criteria harmonization: regulatory frameworks should replace arbitrary chronological age limits with functional capability assessment. Specifically, aviation professionals holding valid medical certificates should be exempt from maximum age restrictions for exit row seating, as their continued medical certification directly attests to their physical and cognitive capability.

Second, positive selection implementation: regulations should establish a hierarchical preference system for exit row allocation, prioritizing (in descending order) aviation professionals with valid certifications, military and emergency services personnel, and passengers who meet enhanced

capability criteria. This approach does not preclude commercial sale of remaining exit row seats but ensures that at least a minimum number of positions per exit are allocated based on capability.

Third, seatbelt extender prohibition in critical positions: regulatory authorities should prohibit the use of seatbelt extenders in exit row seats, the first row, and the last row of the aircraft cabin, establishing a practical and non-discriminatory proxy measure for ensuring adequate passenger mobility in positions critical to evacuation flow.

Fourth, multi-stage verification protocols: a standardized three-layer verification system should be mandated, integrating automated digital screening at purchase and check-in, structured pre-boarding assessment at the gate, and crew-administered verification aboard the aircraft, with explicit authority for immediate passenger reallocation.

Fifth, enhanced briefing procedures: exit row briefings should incorporate procedural elements beyond declarative information transfer, including explicit instruction on the distinction between authorized and premature exit operation, directional guidance for window/door disposal relative to engine placement, and confirmation through passenger feedback rather than passive acknowledgment.

Sixth, structural decoupling: regulatory mechanisms should ensure that emergency exit seat allocation decisions are structurally separated from commercial revenue optimization systems, establishing safety-based allocation as a prerequisite that commercial processes must respect rather than override.

6 Conclusions

This research contributes to aviation safety literature by providing a systematic, multi-method framework for analysing emergency exit passenger selection as a sociotechnical system challenge. The evolutionary integration of HTA, EAST, and WDA demonstrates that these analytical tools provide complementary perspectives: HTA reveals functional task requirements, EAST captures the distributed cognition demands of real-world emergency scenarios, and WDA identifies the systemic constraints that prevent optimal practices from being implemented despite existing technical knowledge.

The six systemic constraints identified through WDA represent addressable barriers to safety optimization. The international regulatory comparison demonstrates that more prescriptive approaches (as exemplified by Japan's JCAB framework) are both feasible and operationally implementable. The proposed shift from exclusion-based to inclusion-based selection represents a paradigm change that aligns passenger selection practices with evidence-based human factors principles.

The aviation industry has an exemplary record of systemic learning and safety improvement. The recommendations presented in this paper offer concrete, evidence-based proposals for regulatory reform that can be implemented within existing operational frameworks. Each proposed measure targets a specific systemic constraint identified through rigorous analysis, ensuring that recommendations are grounded in empirical evidence rather than theoretical speculation. The ultimate objective remains the optimization of a safety-critical system to preserve the maximum number of human lives in emergency situations.

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